Section 1

Describing and Measuring Motion

Objectives

After this lesson, students will be able to

M.1.1.1 Determine when an object is in motion.

M.1.1.2 Calculate an object's speed and velocity.

M.1.1.3 Demonstrate how to graph motion.

Target Reading Skill

Using Prior Knowledge Explain that using prior knowledge helps students connect what they already know to what they are about to read.

Answers

Sample answers:

What You Know

1. A moving object changes position.
2. Objects move at different speeds.

What You Learned

1. Motion is compared to a reference point.
2. The SI unit of length is the meter.

All in One Teaching Resources

- Transparency M1

Preteach

Build Background Knowledge L2

Experience With Motion

Have students discuss motion. Ask: **How do you know an object is moving?** *(Sample answer: An object is moving when it is changing position.)* **How can you decide if an object is moving slowly or quickly?** *(Sample answer: An object is moving slowly if it moves a short distance in a long time.)*

Section 1

Describing and Measuring Motion

Reading Preview

Key Concepts

- When is an object in motion?
- How do you know an object's speed and velocity?
- How can you graph motion?

Key Terms

- motion • reference point
- International System of Units
- meter • speed • average speed
- instantaneous speed
- velocity • slope

Target Reading Skill

Using Prior Knowledge Before you read, write what you know about motion in a graphic organizer like the one below. As you read, write what you learn.

What You Know

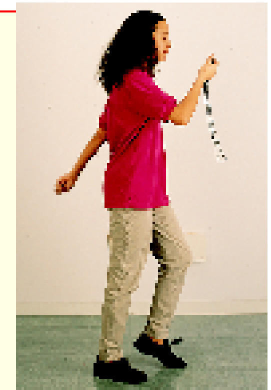
1. A moving object changes position.
2.

What You Learned

1.
2.

Lab zone Discover Activity

How Fast and How Far?



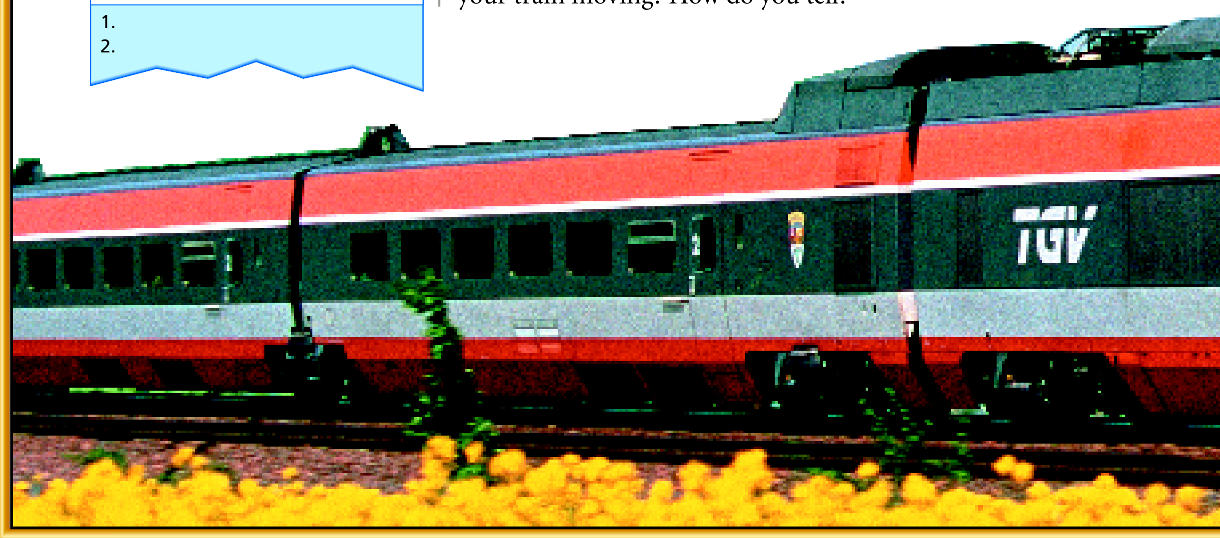
1. Using a stopwatch, find out how long it takes you to walk 5 meters at a normal pace. Record your time.
2. Now find out how far you can walk in 5 seconds if you walk at a normal pace. Record your distance.
3. Repeat Steps 1 and 2, walking slower than your normal pace. Then repeat Steps 1 and 2 walking faster than your normal pace.

Think It Over

Inferring What is the relationship between the distance you walk, the time it takes you to walk, and your walking speed?

How do you know if you are moving? If you've ever traveled on a train, you know you cannot always tell if you are in motion. Looking at a building outside the window helps you decide. Although the building seems to move past the train, it's you and the train that are moving.

However, sometimes you may see another train that appears to be moving. Is the other train really moving, or is your train moving? How do you tell?



Lab zone Discover Activity

Skills Focus Inferring L1

Materials masking tape, meter stick, stopwatch

Time 15 minutes

Tips Use masking tape to mark the starting line, another line 5 meters from the starting line (for Step 1), and the distance walked after 5 seconds (for Step 2). Remind students to walk at a normal pace.

Think It Over The faster you walk, the less time it takes to move a certain distance. The faster you walk, the farther you will travel in a given time. If you walk a longer distance in a given amount of time, you are walking faster.

Describing Motion

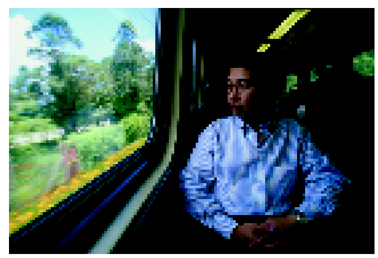
Deciding if an object is moving isn't as easy as you might think. For example, you are probably sitting in a chair as you read this book. Are you moving? Well, parts of you may be. Your eyes blink and your chest moves up and down. But you would probably say that you are not moving. An object is in **motion** if its distance from another object is changing. Because your distance from your chair is not changing, you are not in motion.

Reference Points To decide if you are moving, you use your chair as a reference point. A **reference point** is a place or object used for comparison to determine if something is in motion. **An object is in motion if it changes position relative to a reference point.**

Objects that we call stationary—such as a tree, a sign, or a building—make good reference points. From the point of view of the train passenger in Figure 1, such objects are not in motion. If the passenger is moving relative to a tree, he can conclude that the train is in motion.

You probably know what happens if your reference point is moving. Have you ever been in a school bus parked next to another bus? Suddenly, you think your bus is moving backward. But, when you look out a window on the other side, you find that your bus isn't moving at all—the other bus is moving forward! Your bus seems to move backward because you used the other bus as a reference point.

FIGURE 1
Reference Points
The passenger can use a tree as a reference point to decide if the train is moving. A tree makes a good reference point because it is stationary from the passenger's point of view.
Applying Concepts *Why is it important to choose a stationary object as a reference point?*



Instruct

Describing Motion

Teach Key Concepts L2

Changing Position and Reference Points

Focus Tell students that to determine if an object is in motion it must be compared to another object, called a reference point. Remind students that distance is measured using SI units.

Teach Ask: **Are the passengers in a boat moving compared to a person standing on the shore? Why?** *(Yes, the distance between the passenger and the person on the shore is changing.)* **Are seated passengers in a boat moving compared to the boat? Why?** *(No, the distance between the boat and the passengers does not change.)*

Apply Ask: **Why do scientists need a consistent, accurate way to measure distance when they study motion?** *(Sample answer: So they can compare their work to the work of others)* **learning modality: logical/mathematical**

Independent Practice L2

All in One Teaching Resources

- Guided Reading and Study Worksheet: *Describing and Measuring Motion*

Student Edition on Audio CD

Differentiated Instruction

Less Proficient Readers L1

Interpreting Figures Have students listen while you read aloud the text under the heading Reference Points. After they have completed listening, have students use Figure 1 to help them verbally explain the concept of a reference point. **learning modality: verbal**

Special Needs L1

Modeling Motion Ask pairs of students to model a moving object and a reference point. One student should serve as the reference point, and the other as the moving object. Ask: **How do you know which student in the pair is the reference point?** *(Reference points should not move, so the student who does not move must be the reference point.)* **learning modality: kinesthetic**

Monitor Progress L2

Writing Have students write a paragraph that describes three examples of motion they observed on the way to school today.

Answer

Figure 1 If you choose a moving reference point, you may think that you are moving when you are not or that you are moving faster or slower than you really are.

Integrating Space Science L2

Most early astronomers used Earth as a reference point when they observed the sun, planets, and stars. Based on their observations, they developed a geocentric model of the universe in which Earth is stationary and the sun, planets, and stars revolve around it. A heliocentric model (a model in which Earth and the other planets revolve around the sun) was developed in ancient Greece. In the 1500's the heliocentric model was further developed by Copernicus. Ask: **Why might ancient astronomers have been convinced that the sun, planets, and stars revolve around Earth?** *(Sample answer: From the reference point of the moving Earth, the sun, planets, and stars appear to be moving around Earth.)* **learning modality: verbal**

Use Visuals: Figure 2 L2

Choosing Reference Points

Focus Have the students preview Figure 2 and read the inset captions.

Teach Ask: **Are the skydivers moving if your reference point is on the ground?** *(Sample answer: Yes. The distance between the skydivers and the ground is changing.)*

Apply Ask: **How is your choice of a reference point important when describing motion?** *(Sample answer: Objects that appear to be in motion when compared to one reference point might not be in motion when compared to a different reference point.)* **learning modality: visual**

Relative Motion Are you moving as you read this book? The answer to that question depends on your reference point. When your chair is your reference point, you are not moving. But if you choose another reference point, you may be moving.

Suppose you choose the sun as a reference point instead of your chair. If you compare yourself to the sun, you are moving quite rapidly. This is because you and your chair are on Earth, which moves around the sun. Earth moves about 30 kilometers every second. So you, your chair, this book, and everything else on Earth move that quickly as well. Going that fast, you could travel from New York City to Los Angeles in about 2 minutes! Relative to the sun, both you and your chair are in motion. But because you are moving with Earth, you do not seem to be moving.

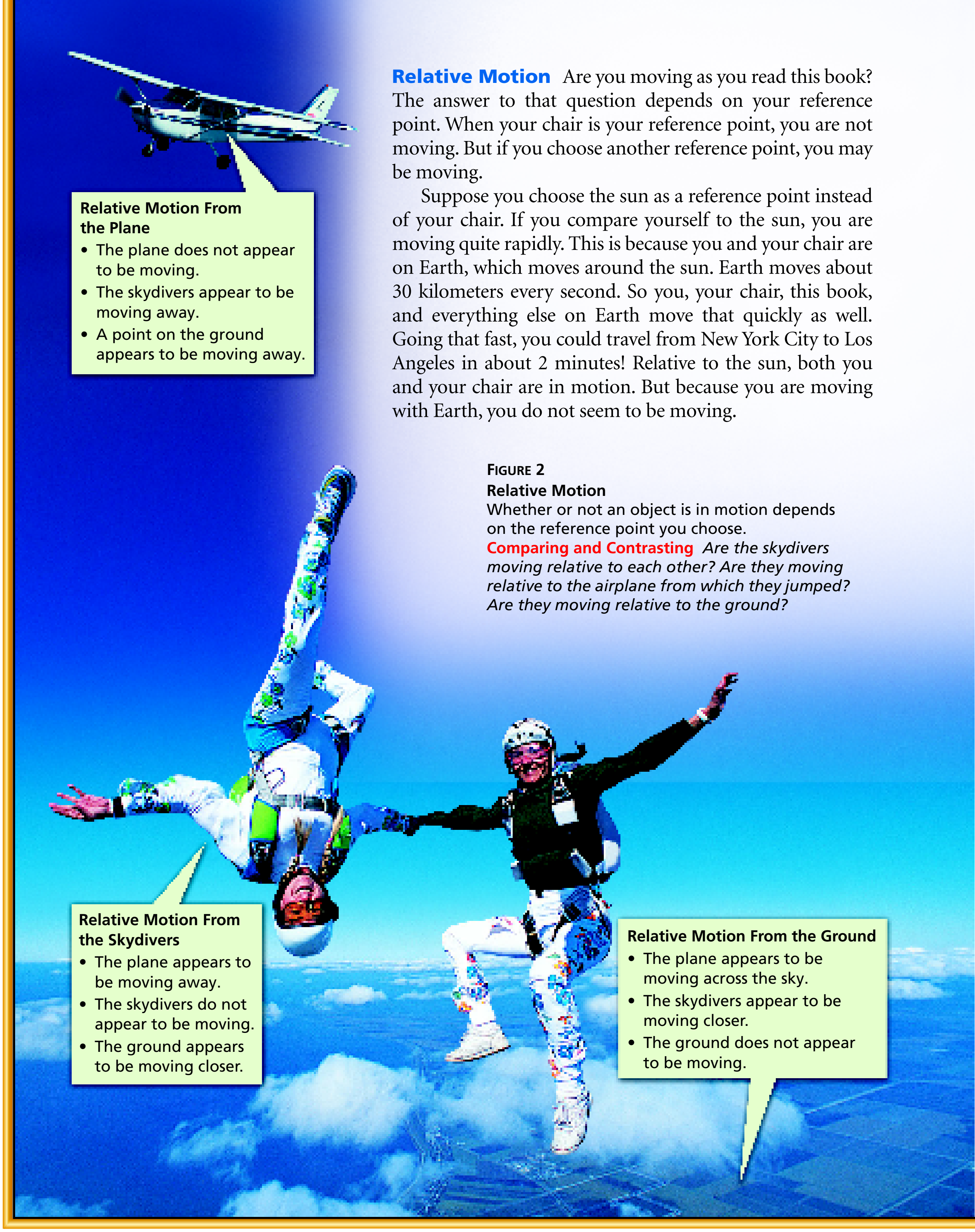


FIGURE 2
Relative Motion
Whether or not an object is in motion depends on the reference point you choose.
Comparing and Contrasting *Are the skydivers moving relative to each other? Are they moving relative to the airplane from which they jumped? Are they moving relative to the ground?*

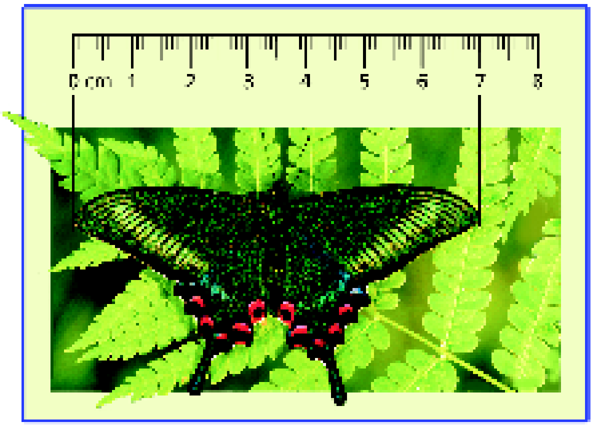


FIGURE 3
Measuring Distance
You can measure distances shorter than 1 meter in centimeters. The wingspan of the butterfly is 7 cm.

Measuring Distance You can use units of measurement to describe motion precisely. You measure in units, or standard quantities of measurement, all the time. For example, you might measure 1 cup of milk for a recipe, run 2 miles after school, or buy 3 pounds of fruit at the store. Cups, miles, and pounds are all units of measurement.

Scientists all over the world use the same system of measurement so that they can communicate clearly. This system of measurement is called the **International System of Units** or, in French, *Système International* (SI).

When describing motion, scientists use SI units to describe the distance an object moves. When you measure distance, you measure length. The SI unit of length is the **meter** (m). A meter is a little longer than a yard. An Olympic-size swimming pool is 50 meters long. A football field is about 91 meters long.

The length of an object smaller than a meter often is measured in a unit called the centimeter (cm). The prefix *centi-* means "one hundredth." A centimeter is one hundredth of a meter, so there are 100 centimeters in a meter. The wingspan of the butterfly shown in Figure 3 can be measured in centimeters. For lengths smaller than a centimeter, the millimeter (mm) is used. The prefix *milli-* means "one thousandth," so there are 1,000 millimeters in a meter. Distances too long to be measured in meters often are measured in kilometers (km). The prefix *kilo-* means "one thousand." There are 1,000 meters in a kilometer.

Scientists also use SI units to describe quantities other than length. You can find more information about SI units in the Skills Handbook at the end of this book.

Reading Checkpoint What system of measurement do scientists use?

Math Skills

Converting Units

Use a conversion factor to convert one metric unit to another. A conversion factor is a fraction in which the numerator and denominator represent equal amounts in different units. Multiply the number you want to convert by the conversion factor.

Suppose you want to know how many millimeters (mm) are in 14.5 meters (m). Since there are 1,000 millimeters in 1 meter, the conversion factor is

$$\frac{1{,}000 \text{ mm}}{1 \text{ m}}$$

Multiply 14.5 meters by the conversion factor to find millimeters.

$$14.5 \text{ m} \times \frac{1{,}000 \text{ mm}}{1 \text{ m}}$$

$$= 14.5 \times 1{,}000 \text{ mm}$$

$$= 14{,}500 \text{ mm}$$

Practice Problem How many centimeters are in 22.5 meters?

Lab zone Build Inquiry L1

Describing Distance

Materials chair; classroom items such as a chalkboard, desk, eraser, meter sticks, sheet of paper, stapler

Time 15 minutes

Focus Remind students that the basic SI unit of distance is the meter. Smaller objects can be measured using centimeters and millimeters.

Teach Have students create a measurement inventory of the classroom using SI units of measure. Have the students determine the appropriate unit for each item measured.

Apply Ask: **What was the smallest object you measured?** *(Sample answer: Paper clip)* **What unit did you use to measure this item?** *(Sample answer: Millimeters)* **learning modality: logical/mathematical**

Math Skills

Skills Focus Converting units

Time 15 minutes

Tips Show students a meter stick that is divided into millimeters. Ask: **If there are 1,000 millimeters on a meter stick, then how many millimeters are on 14.5 meter sticks?** *(14,500 mm)* For the practice problem, point out the centimeter markings on the meter stick.

Answer 22.5 m = 2,250 cm

Extend Have students measure the length and width of the classroom in meters. Then, have students convert these measurements to centimeters and millimeters.

Monitor Progress L2

Skills Check Have students measure the width and length of their index fingers in millimeters and convert the answer to centimeters.

Answers

Figure 2 No, the skydivers are not moving relative to each other. They are moving relative to the airplane and the ground.

Reading Checkpoint Scientists use the International System of Units, or SI.

Calculating Speed

Teach Key Concepts L2

Distance and Time

Focus Tell the students that speed is the distance traveled by an object divided by the time it took to travel that distance.

Teach Write *Speed = Distance/Time* on the board. Have students suggest a fictional distance and time. Use the suggested numbers to calculate a speed. Ask: **What are two ways to increase this speed?** *(Decrease the time or increase the distance traveled)* Show, by calculating, how each of these changes affects speed.

Apply Ask: **How can you compare the motion of two objects?** *(Sample answer: You can calculate the speed at which each object is moving, and compare the speeds.)* **learning modality: logical/mathematical**

Address Misconceptions L1

Differentiating Speed and Quickness

Focus Many students think that objects must move quickly to have speed.

Teach Explain that any object in motion has a speed, or rate of motion. Direct their attention to the clock. Explain that the hour hand has a speed even though it moves slowly. Point out that the word *speedy*, meaning quick, can be misleading.

Apply Ask: **How do you know that all objects in motion have a speed?** *(Sample answer: Because all objects in motion travel some distance, they all have a speed.)* **learning modality: visual**

Lab zone Skills Activity

Calculating

Two families meet at the City Museum at 10:00 A.M. Each family uses a different means of transportation to get there. The Gonzalez family leaves at 9:00 A.M. and drives 90 km on a highway. The Browns leave at 9:30 A.M. and ride the train 30 km. What is the average speed for each family's trip? Which family travels at the faster speed?

Calculating Speed

A measurement of distance can tell you how far an object travels. A cyclist, for example, might travel 30 kilometers. An ant might travel 2 centimeters. **If you know the distance an object travels in a certain amount of time, you can calculate the speed of the object.** Speed is a type of rate. A rate tells you the amount of something that occurs or changes in one unit of time. The **speed** of an object is the distance the object travels per unit of time.

The Speed Equation To calculate the speed of an object, divide the distance the object travels by the amount of time it takes to travel that distance. This relationship can be written as an equation.

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

The speed equation consists of a unit of distance divided by a unit of time. If you measure distance in meters and time in seconds, you express speed in meters per second, or m/s. (The slash is read as "per.") If you measure distance in kilometers and time in hours, you express speed in kilometers per hour, or km/h. For example, a cyclist who travels 30 kilometers in 1 hour has a speed of 30 km/h. An ant that moves 2 centimeters in 1 second is moving at a speed of 2 centimeters per second, or 2 cm/s.

FIGURE 4
Speed
The cyclists' speeds will vary throughout the cross-country race. However, the cyclist with the greatest average speed will win.

Lab zone Skills Activity

Skills Focus Calculating L2

Time 5 minutes

Tips Pair students of differing ability levels for this activity.

Answer The Gonzalez family traveled at a speed of 90 km/h; the Browns traveled at 60 km/h. The Gonzalez family traveled at the faster speed.

Extend Ask: **At the same speed, how long would the Brown family need to ride the train to get to a destination 150 km from their home?** *(2.5 hours)* **learning modality: logical/mathematical**

Average Speed The speed of most moving objects is not constant. The cyclists shown in Figure 4, for example, change their speeds many times during the race. They might ride at a constant speed along flat ground but move more slowly as they climb hills. Then they might move more quickly as they come down hills. Occasionally, they may stop to fix their bikes.

Although a cyclist does not have a constant speed, the cyclist does have an average speed throughout a race. To calculate **average speed**, divide the total distance traveled by the total time. For example, suppose a cyclist travels 32 kilometers during the first 2 hours. Then the cyclist travels 13 kilometers during the next hour. The average speed of the cyclist is the total distance divided by the total time.

$$\text{Total distance} = 32\text{ km} + 13\text{ km} = 45\text{ km}$$
$$\text{Total time} = 2\text{ h} + 1\text{ h} = 3\text{ h}$$
$$\text{Average speed} = \frac{45\text{ km}}{3\text{ h}} = 15\text{ km/h}$$

The cyclist's average speed is 15 kilometers per hour.

Instantaneous Speed Calculating the average speed of a cyclist during a race is important. However, it is also useful to know the cyclist's instantaneous speed. **Instantaneous speed** is the rate at which an object is moving at a given instant in time.

Reading Checkpoint How do you calculate average speed?

FIGURE 5
Measuring Speed
Cyclists use an electronic device known as a cyclometer to track the distance and time that they travel. A cyclometer can calculate both average and instantaneous speed.
Comparing and Contrasting
How does average speed compare to instantaneous speed?

Lab zone Build Inquiry L2

Measuring Speed

Materials masking tape, metric rulers, stopwatches, two or three wind-up toys per group

Time 10 minutes

Focus Remind students that speed is the distance traveled in a period of time.

Teach Have students mark a measured distance on the floor with masking tape. Have students measure the time needed for each toy to travel the marked distance. Suggest that students perform three or more trials for each toy, and average the results. Students can use their results to calculate the speed of each toy.

Apply Ask: **For each trial, are you measuring instantaneous speed or average speed?** *(Average speed)* **learning modality: kinesthetic**

Differentiated Instruction

English Learners/Beginning L1
Vocabulary: Link to Visual Point out Figure 5, which shows the cyclist's instantaneous speed and average speed. Read the caption aloud for students. Ask: **What is this cyclist's average speed?** *(15 km/h)* **What is this cyclist's instantaneous speed?** *(22 km/h)* **learning modality: visual**

English Learners/Intermediate L2
Vocabulary: Link to Visual Have students examine Figure 5 and read the caption. Then have students write a sentence comparing the average and instantaneous speed of the cyclists. Ask for volunteers to read their sentences aloud. **learning modality: verbal**

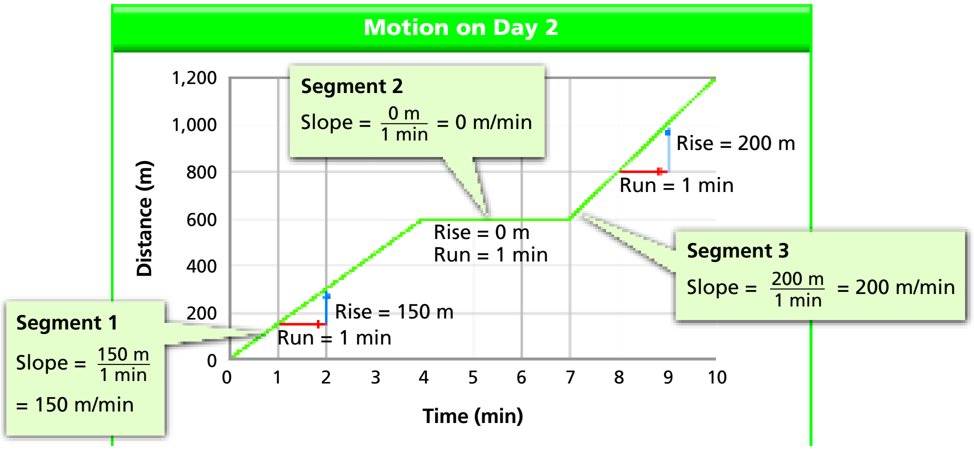
Monitor Progress L2

Skills Check Have students find the speed of an asteroid that travels 4,500 km in 60 s. *(4,500 km ÷ 60 s = 75 km/s)*

Answers

Figure 5 The instantaneous speed of the cyclist is faster than the average speed.

Reading Checkpoint Average speed = total distance/total time



Different Slopes Most moving objects do not travel at a constant speed. The graph above shows a jogger's motion on her second day. The line is divided into three segments. The slope of each segment is different. From the steepness of the slopes you can tell that the jogger ran the fastest during the third segment. The horizontal line in the second segment shows that the jogger's distance did not change at all.

Section 1 Assessment

Target Reading Skill
Using Prior Knowledge Review your graphic organizer and revise it based on what you just learned about motion.

Reviewing Key Concepts

1. a. **Reviewing** How do you know if an object is moving?
   b. **Explaining** Why is it important to know if your reference point is moving?
   c. **Applying Concepts** Suppose you are riding in a car. Describe your motion relative to the car, the road, and the sun.
2. a. **Defining** What is speed?
   b. **Describing** What do you know about the motion of an object that has an average speed of 1 m/s?
   c. **Comparing and Contrasting** What is the difference between speed and velocity?
3. a. **Identifying** What does the slope of a distance-versus-time graph show you about the motion of an object?
   b. **Calculating** The rise of a line on a distance-versus-time graph is 600 m and the run is 3 minutes. What is the slope of the line?

Math Practice

This week at swim practice, Jamie swam a total of 1,500 m, while Ellie swam 1.6 km.

4. **Converting Units** Convert Ellie's distance to meters. Who swam the greater distance: Jamie or Ellie?
5. **Converting Units** How many kilometers did Jamie swim?

Monitor Progress L2

Answers
Figure 6 1,000 m
Reading Checkpoint The steepness of the line; it tells how fast one variable changes as compared to the other.

Assess

Reviewing Key Concepts

1. a. You know an object is moving if it changes its position relative to a stationary reference point. **b.** If your reference point is moving, you will find it difficult to determine which direction you are moving or even if you are moving at all. **c.** You are stationary relative to the car and moving relative to the road. As long as your car is moving in a straight line, the sun does not appear to move much in a short period of time, so it appears that you are almost motionless relative to the sun.
2. a. Speed is distance traveled per unit time. **b.** You know that the object has traveled an average of 1 m each second over a period of time, although its speed may have varied or the object may have even stopped during that time. **c.** Speed describes the rate at which something moves. Velocity is speed in a given direction.
3. a. The slope of a distance-versus-time graph shows you the speed of the moving object. **b.** The slope is 200 m/min.

Reteach L1

Have students work in pairs to review the definition of the terms *velocity, speed,* and *motion.*

Performance Assessment L2

Skills Check Give each student a copy of the same map. Ask them to use the scale to find the distance in kilometers between two points (A and B) they choose. Have each student determine the speed required to get from point A to point B in two hours.

All in One Teaching Resources
- Section Summary: *Describing and Measuring Motion*
- Review and Reinforce: *Describing and Measuring Motion*
- Enrich: *Describing and Measuring Motion*

Math Practice

Math Skill Converting units

Answers
4. Ellie's distance: 1.6 km × 1,000 m/1 km = 1,600 m; Ellie swam farther than Jamie.
5. 1.5 km

Lab zone Chapter Project

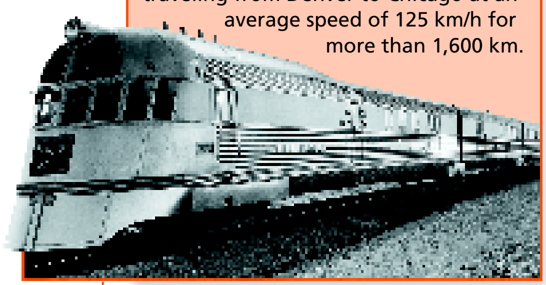
Keep Students on Track Provide a model for students of how to record the data from the project. You may want to model how to make the measurements, how to construct a data table, and how to perform the required calculations. Instruct students to choose the best units for each speed measurement.

At times, describing the velocity of moving objects can be very important. For example, air traffic controllers must keep close track of the velocities of the aircraft under their control. These velocities continually change as airplanes move overhead and on the runways. An error in determining a velocity, either in speed or in direction, could lead to a collision.

Velocity is also important to airplane pilots. For example, stunt pilots make spectacular use of their control over the velocity of their aircrafts. To avoid colliding with other aircraft, these skilled pilots must have precise control of both their speed and direction. Stunt pilots use this control to stay in close formation while flying graceful maneuvers at high speed.

Reading Checkpoint What is velocity?

1934 Zephyr Introduced
The first diesel passenger train in the United States was the *Zephyr.* The *Zephyr* set a long-distance record, traveling from Denver to Chicago at an average speed of 125 km/h for more than 1,600 km.



1956 Interstate Highway System Established
The passage of the Federal-Aid Highway Act established the Highway Trust Fund. This act allowed the construction of the Interstate and Defense Highways. Nonstop transcontinental auto travel became possible. Speed limits in many parts of the system were more than 100 km/h.

2003 Maglev in Motion
The first commercial application of high-speed maglev (magnetic levitation) was unveiled in Shanghai, China. During the 30-km trip from Pudong International Airport to Shanghai's financial district, the train operates at a top speed of 430 km/h, reducing commuting time from 45 minutes to just 8 minutes.

1950 2000 2050

Writing in Science
Research and Write What styles of automobile were most popular during the 1950s, 1960s, and 1970s? Were sedans, convertibles, station wagons, or sports cars the bestsellers? Choose an era and research automobiles of that time. Then write an advertisement for one particular style of car. Be sure to include information from your research.

• Tech & Design in History •
Focus Review each item along the timeline with students.

Teach Point out the speeds at which each of the vehicles traveled. Ask: **How do you think improvements in transportation affected the lives of people at that time?** *(Sample answer: They were able to travel farther to find a job, get supplies, or visit relatives.)* **What do you think are some negative effects of widespread rapid transportation?** *(Sample answer: Increased pollution and accidents)*

Writing in Science
Writing Mode Research and write

Scoring Rubric

4 Exceeds criteria; includes a well-written advertisement with detailed information

3 Meet criteria

2 Advertisement is brief and/or not thoroughly researched

1 Advertisement is incomplete and/or includes numerous errors

Students can save their writing in their portfolio. Portfolio

Differentiated Instruction
Special Needs L1
Classifying Organize students into small groups. Have students make a poster that includes pictures or drawings of various types of transportation. The pictures can be classified as "types of transportation used today" and "types of transportation used in the past." Have students indicate which group moves at a greater speed. **learning modality: visual**

Gifted and Talented L3
Communicating Have students research the changes in highway speed limits that have occurred from the 1950's through the present. Students should relate changes in speed limits to changes in automotive technology. Students can report their findings to the class. **learning modality: verbal**

Monitor Progress L2
Writing Have students compare the terms *speed* and *velocity.*

Answer

Reading Checkpoint Velocity is speed in a given direction.

Graphing Motion

Teach Key Concepts

L2

Distance Against Time

Focus Tell students that an object's motion can be shown on a line graph. Distance and time are the two variables shown on a motion graph.

Teach Direct students' attention to Figure 6. Ask: **In the first seven minutes of day 1, does the jogger move at a constant speed? How do you know?** *(Sample answer: Yes; because the graph is a straight line, I can tell that the jogger traveled the same distance in each time interval.)*

Apply Ask: **What would the graph look like if the jogger ran at a constant rate, but much slower than the jogger on Day 1?** *(The graph would be a straight line, but its slope would be less steep.)* **learning modality: logical/mathematical**

All in One Teaching Resources

- Transparencies M2, M3

Go Online active art

For: Motion activity
Visit: PHSchool.com
Web Code: cgp-3011

Students can interact with the distance-versus-time graphs online.

Lab zone Build Inquiry

L3

Motion Graphs

Materials graph paper, masking tape, measuring tape, pencils, stopwatch

Time 15 minutes

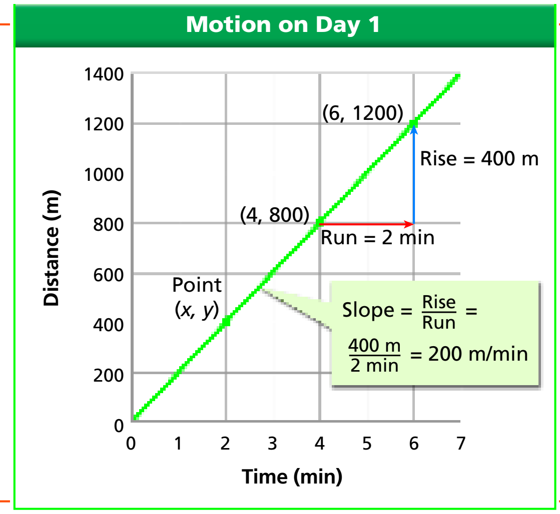
Focus Draw students' attention to the motion graphs in the text. Remind students that to graph motion, time and distance traveled are measured.

Teach Tell students they will be making a motion graph. Students can work in small groups or as a class. Have students mark a starting line in the hallway or outdoors. Then have a student start at the line and walk at a normal pace. Have another student mark with tape the distance traveled at 30-second intervals for a total of 2 minutes. Have students measure the distance traveled during each time period, and use their data to make a motion graph.

Go Online active art

For: Graphing Motion activity
Visit: PHSchool.com
Web Code: cgp-3011

FIGURE 6
Graphing Motion
Distance-versus-time graphs can be used to analyze motion. On the jogger's first day of training, her speed is the same at every point. On the second day of training, her speed varies. **Reading Graphs** *On the first day, how far does the jogger run in 5 minutes?*



Graphing Motion

You can show the motion of an object on a line graph in which you plot distance versus time. The graphs you see in Figure 6 are distance-versus-time motion graphs. Time is shown on the horizontal axis, or *x*-axis. Distance is shown on the vertical axis, or *y*-axis. A point on the line represents the distance an object has traveled at a particular time. The *x* value of the point is time, and the *y* value is distance.

The steepness of a line on a graph is called **slope.** The slope tells you how fast one variable changes in relation to the other variable in the graph. In other words, slope tells you the rate of change. Since speed is the rate that distance changes in relation to time, the slope of a distance-versus-time graph represents speed. The steeper the slope is, the greater the speed. A constant slope represents motion at constant speed.

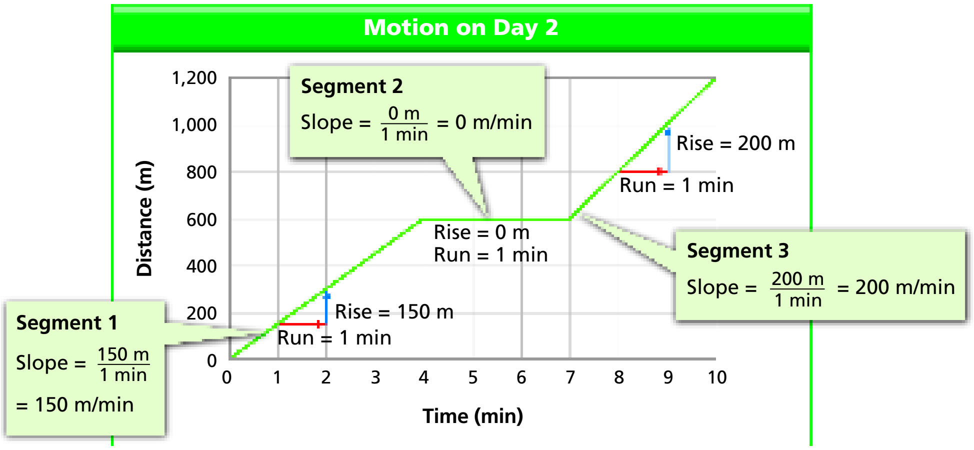
Calculating Slope You can calculate the slope of a line by dividing the rise by the run. The rise is the vertical difference between any two points on the line. The run is the horizontal difference between the same two points.

$$\text{Slope} = \frac{\text{Rise}}{\text{Run}}$$

In Figure 6, using the points shown, the rise is 400 meters and the run is 2 minutes. To find the slope, you divide 400 meters by 2 minutes. The slope is 200 meters per minute.

Reading Checkpoint What is the slope of a graph?

Apply Ask: **On a motion graph, how can you tell if the student took a 30-second break?** *(The line for that time period would be flat.)* **learning modality: logical/mathematical**



Different Slopes Most moving objects do not travel at a constant speed. The graph above shows a jogger's motion on her second day. The line is divided into three segments. The slope of each segment is different. From the steepness of the slopes you can tell that the jogger ran the fastest during the third segment. The horizontal line in the second segment shows that the jogger's distance did not change at all.

Section 1 Assessment

Target Reading Skill

Using Prior Knowledge Review your graphic organizer and revise it based on what you just learned about motion.

Reviewing Key Concepts

1. a. **Reviewing** How do you know if an object is moving?
   b. **Explaining** Why is it important to know if your reference point is moving?
   c. **Applying Concepts** Suppose you are riding in a car. Describe your motion relative to the car, the road, and the sun.
2. a. **Defining** What is speed?
   b. **Describing** What do you know about the motion of an object that has an average speed of 1 m/s?
   c. **Comparing and Contrasting** What is the difference between speed and velocity?
3. a. **Identifying** What does the slope of a distance-versus-time graph show you about the motion of an object?
   b. **Calculating** The rise of a line on a distance-versus-time graph is 600 m and the run is 3 minutes. What is the slope of the line?

Math Practice

This week at swim practice, Jamie swam a total of 1,500 m, while Ellie swam 1.6 km.

4. **Converting Units** Convert Ellie's distance to meters. Who swam the greater distance: Jamie or Ellie?
5. **Converting Units** How many kilometers did Jamie swim?

Math Practice

Math Skill Converting units

Answers

4. Ellie's distance: 1.6 km × 1,000 m/1 km = 1,600 m; Ellie swam farther than Jamie.
5. 1.5 km

Lab zone Chapter Project

Check Your Progress Provide a model for students of how to record the data from the project. You may want to model how to make the measurements, how to construct a data table, and how to perform the required calculations. Instruct students to choose the best units for each speed measurement.

Monitor Progress L2

Answers

Figure 6 1,000 m

Reading Checkpoint The steepness of the line; it tells how fast one variable changes as compared to the other.

Assess

Reviewing Key Concepts

1. a. You know an object is moving if it changes its position relative to a stationary reference point. **b.** If your reference point is moving, you will find it difficult to determine which direction you are moving or even if you are moving at all. **c.** You are stationary relative to the car and moving relative to the road. As long as your car is moving in a straight line, the sun does not appear to move much in a short period of time, so it appears that you are almost motionless relative to the sun.
2. a. Speed is distance traveled per unit time. **b.** You know that the object has traveled an average of 1 m each second over a period of time, although its speed may have varied or the object may have even stopped during that time. **c.** Speed describes the rate at which something moves. Velocity is speed in a given direction.
3. a. The slope of a distance-versus-time graph shows you the speed of the moving object. **b.** The slope is 200 m/min.

Reteach L1

Have students work in pairs to review the definition of the terms *velocity, speed,* and *motion.*

Performance Assessment L2

Skills Check Give each student a copy of the same map. Ask them to use the scale to find the distance in kilometers between two points (A and B) they choose. Have each student determine the speed required to get from point A to point B in two hours.

All in One Teaching Resources

- Section Summary: *Describing and Measuring Motion*
- Review and Reinforce: *Describing and Measuring Motion*
- Enrich: *Describing and Measuring Motion*

Lab zone Skills Lab

Inclined to Roll

L2

Prepare for Inquiry

Key Concept

The steepness of a ramp affects the speed at which an object moves after rolling off of it.

Skills Objectives

After this lab, students will be able to

- calculate speed using time and distance
- measure the effect of an incline on speed
- graph average speed versus the angle of the ramp

Prep Time 1 hour
Class Time 40 minutes

Advance Planning

Teach or review the skill of measuring, found in the Skills Handbook. Obtain 4 ft × 8 ft sheets of 1/2-in plywood or pegboard, and have them cut crosswise into six ramps, each 16 in. wide. This lab requires plenty of space, and may be done outside or in a gym.

Alternative Materials

Students can share skateboards or use other four-wheeled toys. Instead of using protractors, students can measure the height of the ramp. This measurement can be used instead of the angle to measure ramp incline.

Safety

Tell students to be careful when carrying boards. Tell students not to stand on the skateboards or roll them at other people. Review the safety guidelines in Appendix A.

All in One Teaching Resources

- Lab Worksheet: *Inclined to Roll*

Guide Inquiry

Invitation

Have students predict results. Ask: **Have you ever ridden a bicycle down a hill?** *(Most students will say yes.)* **How did the incline of the hill affect your average speed?** *(Sample answer: Speed is faster after a steeper hill.)*

Lab zone Skills Lab

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Inclined to Roll

Problem

How does the steepness of a ramp affect how fast an object rolling off it moves across the floor?

Skills Focus

measuring, calculating, graphing

Materials

- skateboard
- meter stick
- protractor
- masking tape
- flat board, about 1.5 m long
- small piece of sturdy cardboard
- supports to prop up the board (books, boxes)
- two stopwatches

Procedure

1. In your notebook, make a data table like the one below. Include space for five angles.
2. Lay the board flat on the floor. Using masking tape, mark a starting line in the middle of the board. Mark a finish line on the floor 1.5 m beyond one end of the board. Place a barrier after the finish line.
3. Prop up the other end of the board to make a slight incline. Use a protractor to measure the angle that the board makes with the ground. Record the angle in your data table.
4. Working in groups of three, have one person hold the skateboard so that its front wheels are even with the starting line. As the holder releases the skateboard, the other two students should start their stopwatches.
5. One timer should stop his or her stopwatch when the front wheels of the skateboard reach the end of the incline.
6. The second timer should stop his or her stopwatch when the front wheels reach the finish line. Record the times in your data table in the columns labeled Time 1 and Time 2.
7. Repeat Steps 4–6 two more times. If your results for the three times aren't within 0.2 second of one another, carry out more trials.

Data Table

Angle (degrees)	Trial Number	Time 1 (to bottom) (s)	Time 2 (to finish) (s)	Avg Time 1 (s)	Avg Time 2 (s)	Avg Time 2 – Avg Time 1 (s)	Avg Speed (m/s)
	1						
	2						
	3						
	1						
	2						
	3						
	1						
	2						

Introduce the Procedure

Refer students to the photo illustrating the experimental setup. Show students how to use a stopwatch. Have students roll the skateboard down the ramp a few times to practice using the stopwatches.

Troubleshooting the Experiment

- Make sure the students begin with a very small incline.
- Make sure the skateboard rolls smoothly at the transition from the ramp to the ground.

8. Repeat Steps 3–7 four more times, making the ramp gradually steeper each time.
9. For each angle of the incline, complete the following calculations and record them in your data table.
   a. Find the average time the skateboard takes to get to the bottom of the ramp (Time 1).
   b. Find the average time the skateboard takes to get to the finish line (Time 2).
   c. Subtract the average of Time 1 from the average of Time 2.

Analyze and Conclude

1. **Calculating** How can you find the average speed of the skateboard across the floor for each angle of the incline? Determine the average speed for each angle and record it in your data table.
2. **Classifying** Which is your manipulated variable and which is your responding variable in this experiment? Explain. (For a discussion of manipulated and responding variables, see the Skills Handbook.)
3. **Graphing** On a graph, plot the average speed of the skateboard (on the y-axis) against the angle of the ramp (on the x-axis).
4. **Drawing Conclusions** What does your graph show about the relationship between the skateboard's speed and the angle of the ramp?
5. **Measuring** If your measurements for distance, time, or angle were inaccurate, how would your results have been affected?
6. **Communicating** Do you think your method of timing was accurate? Did the timers start and stop their stopwatches exactly at the appropriate points? How could the accuracy of the timing be improved? Write a brief procedure for your method.

Design an Experiment

A truck driver transporting new cars needs to roll the cars off the truck. You offer to design a ramp to help with the task. What measurements would you make that might be useful? Design an experiment to test your ideas. *Obtain your teacher's permission before carrying out your investigation.*

Expected Outcome

As the ramp incline increases, Average Time 1 will decrease. As the ramp incline increases, the time taken to reach the finish line will decrease.

Analyze and Conclude

1. Average speed on floor is distance traveled on floor (from bottom of ramp to finish line, 1.5 m) divided by time on floor (Average time 2 – Average time 1).

2. Manipulated variable—ramp incline; responding variable—average speed. You vary the ramp incline to determine its relationship to the skateboard's average speed.

3. Graphs should show an increase in average speed when the angle of the ramp increases.

4. Speed increases as ramp incline angle increases.

5. Inaccurate measurements for distance, time, or angle would have caused average speeds to be inaccurate, too.

6. Sample answer: Yes, I think our method of measurement is accurate. To improve accuracy several students could time a particular run, and then the average time could be used. Alternatively, you could employ an electronic timing device, such as the ones used for downhill skiing and other athletic events.

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Students can go online to pool and analyze their data with students nationwide.

Extend Inquiry

Design an Experiment To make the ramp wide enough and strong enough, students need to know the weights of the cars and the distances between the left and right wheels.